

## MIXED FORMULATION FOR MODELLING SELF-CENTRING POST-TENSIONED ROCKING BEAMS AND COLUMNS

Chin-Long Lee<sup>1</sup>

<sup>1</sup> University of Canterbury, Department of Civil and Natural Resources Engineering, Private Bag 4800, Christchurch, New Zealand, chin-long.lee@canterbury.ac.nz,  
<http://www.civil.canterbury.ac.nz/staff/cllee.shtml>

**Key Words:** *Mixed Formulation, Exact Force Interpolation, Rocking Beam, Rocking Column, Self-Centring, Post-Tensioned.*

In finite element modelling of beams and columns, mixed formulation with exact interpolation of force distribution inside the element has been shown to offer significant advantages over most other traditional displacement formulations in terms of accuracy, efficiency and robustness [1-3]. In recent studies, this formulation has been extended to incorporate the effects of energy release via the interface relative slip between constituent components in composite beams and reinforced concrete columns [4-6]. This extended mixed formulation has shown great potential in accurately predicting not only global force-displacement response, but also local stress-strain response.

In this study this mixed formulation will be extended further to incorporate the effects of allowing fixed-end rotations and crack-openings within one component of the composite element while maintaining the displacement continuity of other components. This new mixed formulation can be readily applied to model PRESSS (PREcast Seismic Structural System), which is built by joining prefabricated beams and columns with unbonded post-tensioning tendons and with or without energy dissipating devices at the joints [7-9]. The response of such structural system is usually characterized by self-centring “flag-shape” hysteresis loops with rocking motions at the joints.

The advantages of this newly extended mixed formulation will be demonstrated by comparing numerical results and experimental results of a post-tensioned timber column undergone a series of bi-axial loadings [10-11].

### REFERENCES

- [1] E. Spacone, F.C. Filippou and F.F. Taucer, Fibre beam-column model for non-linear analysis of R/C frames: Part I. Formulation, *Earthquake Engineering and Structural Dynamics*, Vol. **25**, No. 7, pp. 711–726, 1996.
- [2] A. Neuenhofer and F.C. Filippou, Evaluation of nonlinear frame finite-element models, *Journal of Structural Engineering*, Vol. **123**, No. 7, pp. 958–966, 1997.
- [3] C.-L. Lee and F.C. Filippou, Frame elements with mixed formulation for singular section response, *International journal for numerical methods in engineering*, Vol. **78**, No. 11, pp. 1320–1344, 2009.

- [4] C.-L. Lee, *Hu-Washizu 3d frame formulations including bond-slip and singular section response*, Doctoral Dissertation, University of California, Berkeley, 2008.
- [5] C.-L. Lee and F.C. Filippou, Mixed Formulation for Composite and RC Frame Element with Bond-Slip, *Structures Congress 2010@ s19th Analysis and Computation Specialty Conference*, ASCE, pp. 516–526, 2010.
- [6] C.-L. Lee and F.C. Filippou, Evaluation of Mixed Formulation for Modelling RC Columns with Bond Slip, *1st Australasian conference on Computational mechanics (ACCM2013)*, Sydney, 3–4 October 2013
- [7] M.N. Priestley, Overview of PRESSSS research program, *PCI Journal*, Vol. **36**, No. 4, pp. 50–57, 1991.
- [8] M.N. Priestley, The PRESSSS Program—Current Status and Proposed Plans for Phase III, *PCI Journal*, Vol. **41**, No. 2, pp. 22–40, 1996.
- [9] M.N. Priestley, S. Sritharan, J.R. Conley and S. Pampanin, Preliminary results and conclusions from the PRESSSS five-story precast concrete test building, *PCI Journal*, Vol. **44**, No. 6, pp. 42–67, 1999.
- [10] A. Iqbal, S. Pampanin and A. Buchanan, Seismic Behaviour of Prestressed Timber Columns under Bi-directional Loading, *Proceedings of the 10th World Conference on Timber Engineering (WCTE 2008)*, Miyazaki, Japan, 8pp, 2–5 Jun 2008.
- [11] A. Iqbal, *Seismic Response and Design of Subassemblies for Multi-storey Prestressed Timber Buildings*, Doctoral Dissertation, University of Canterbury, 2011.